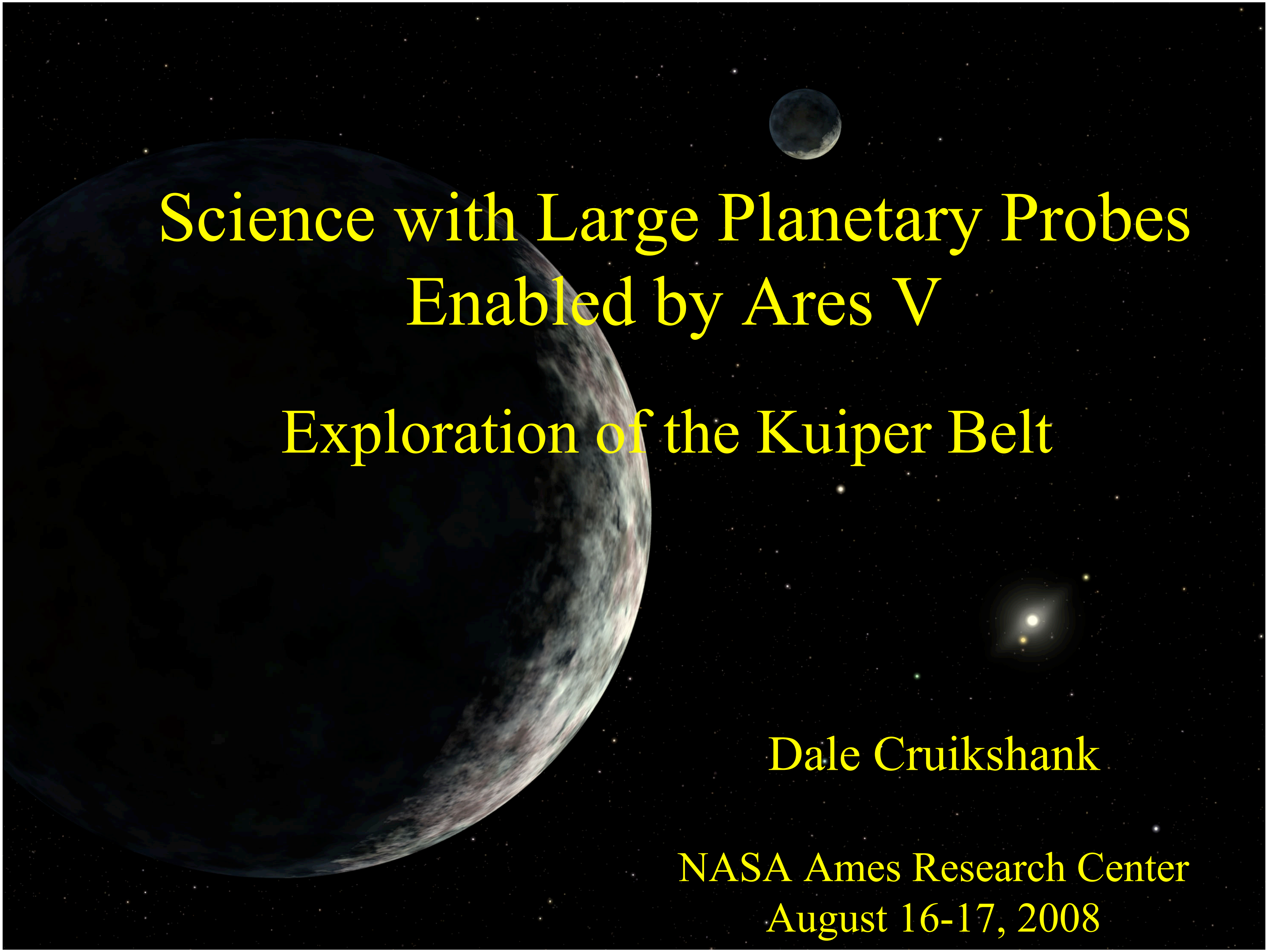


Science with Large Planetary Probes Enabled by Ares V

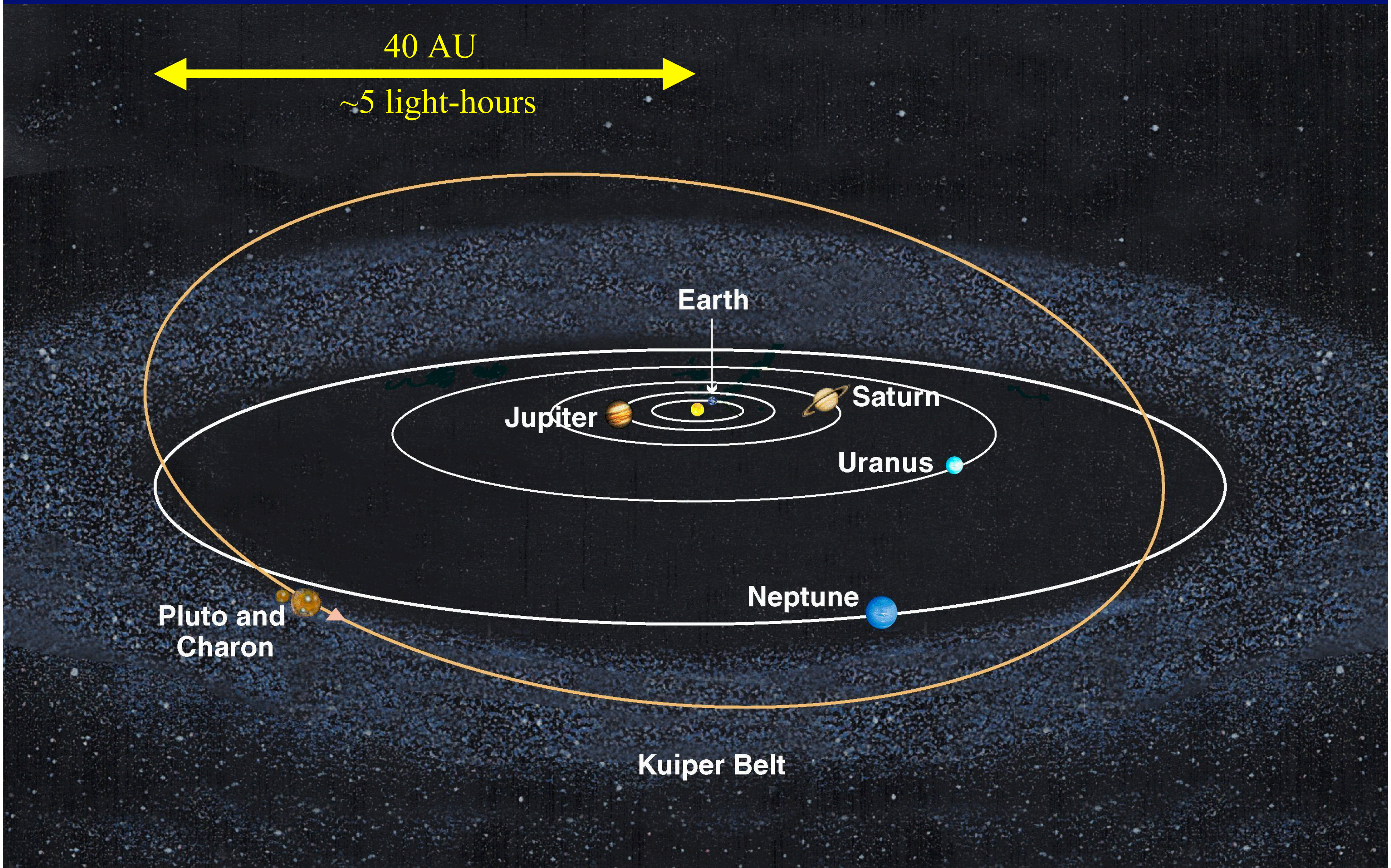
Exploration of the Kuiper Belt

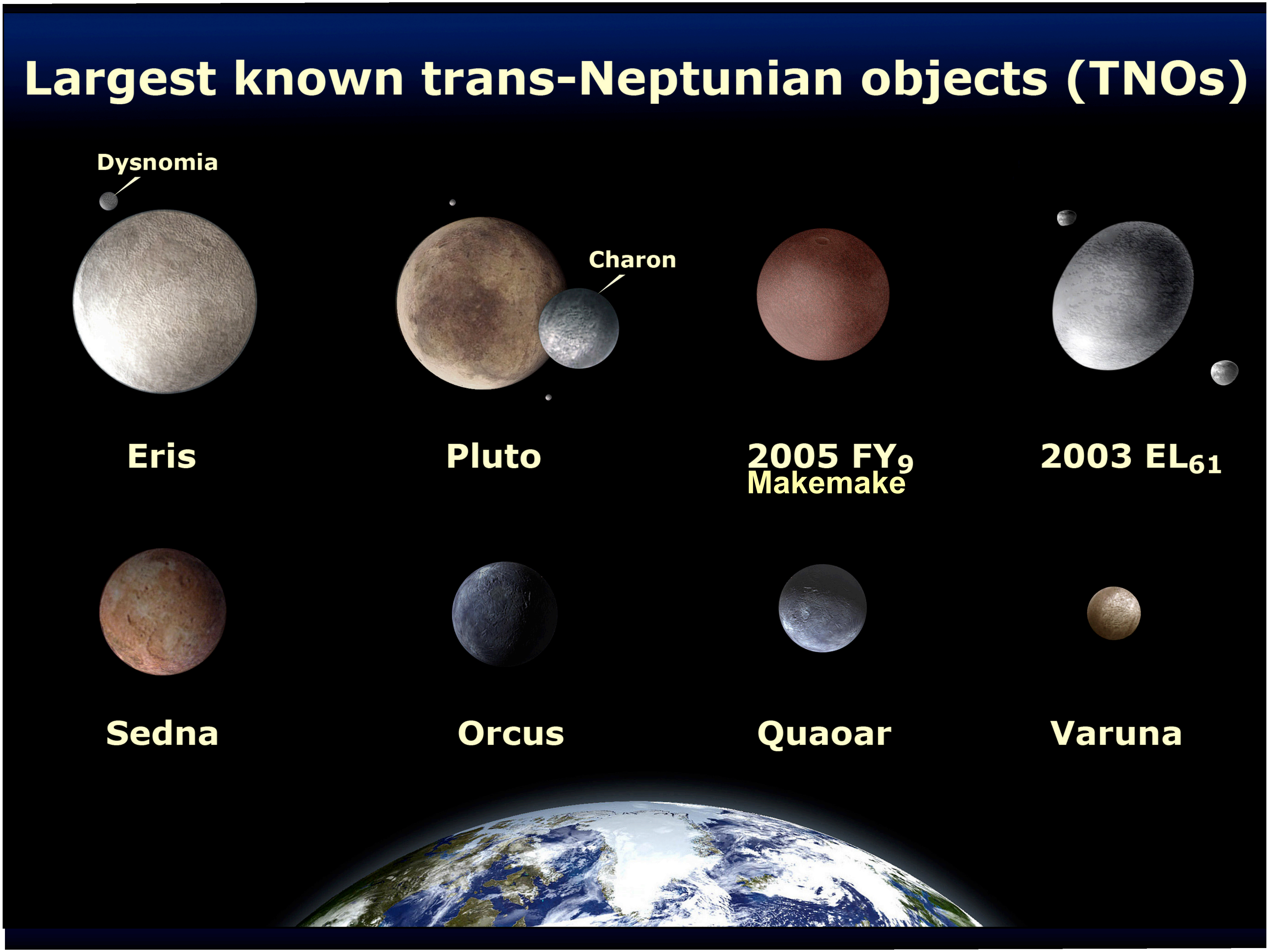
Dale Cruikshank

NASA Ames Research Center

August 16-17, 2008

The Outer Solar System



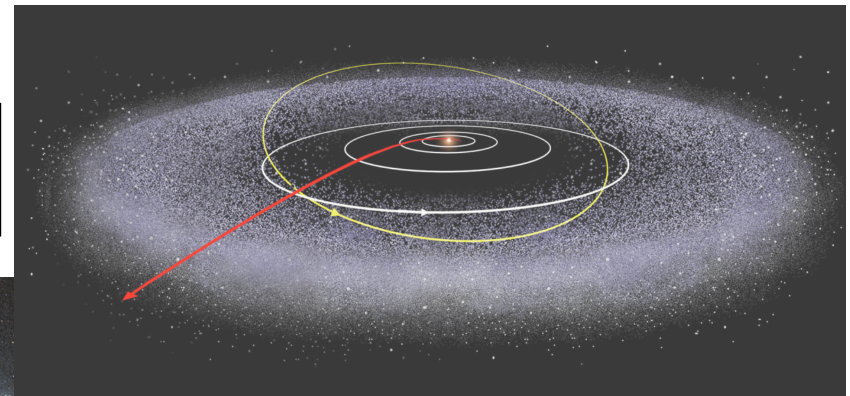


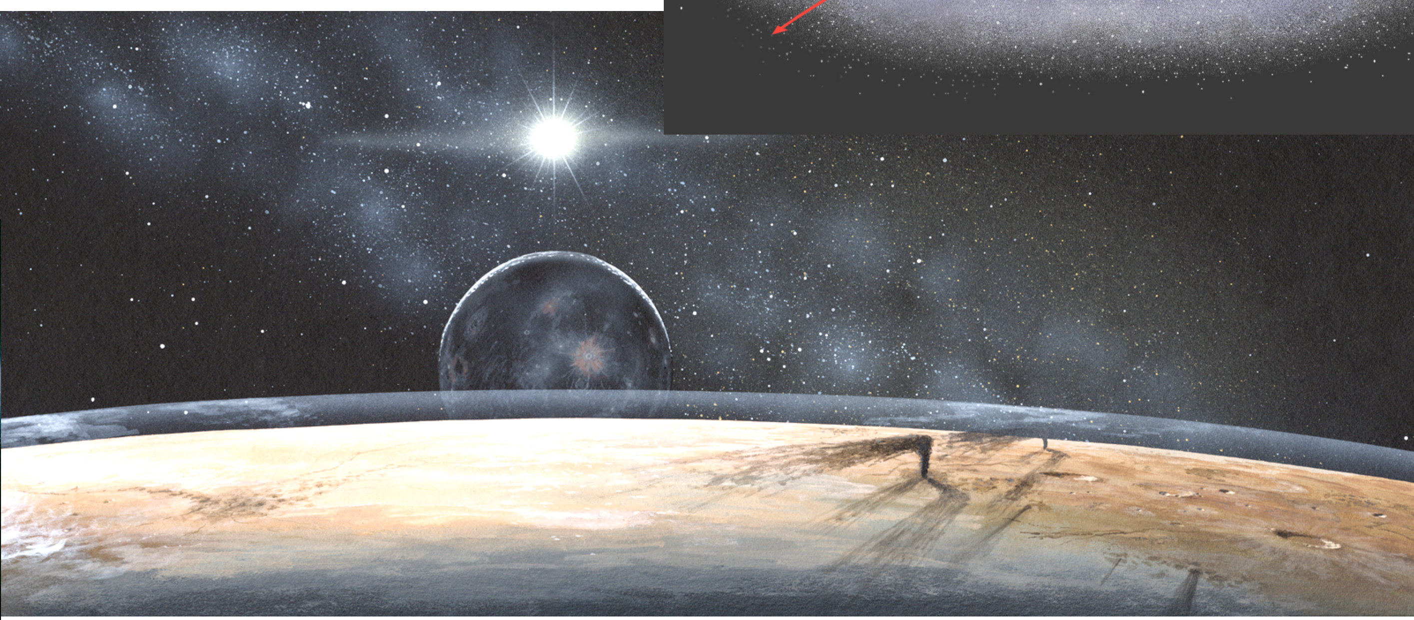
Largest known trans-Neptunian objects (TNOs)
Dysnomia
Charon
Eris
Pluto
2005 FY_9
Makemake
2003 EL_{61}
Sedna
Orcus
Quaoar
Varuna

Toward New Horizons

A Reconnaissance Expedition to Pluto-Charon and the Kuiper Belt

The Highest Priority New Start Recommendation of the NRC's Planetary Decadal Survey (2002).





Launch of *New Horizons*, Atlas V 551 with Star 48B upper stage

January 19, 2006

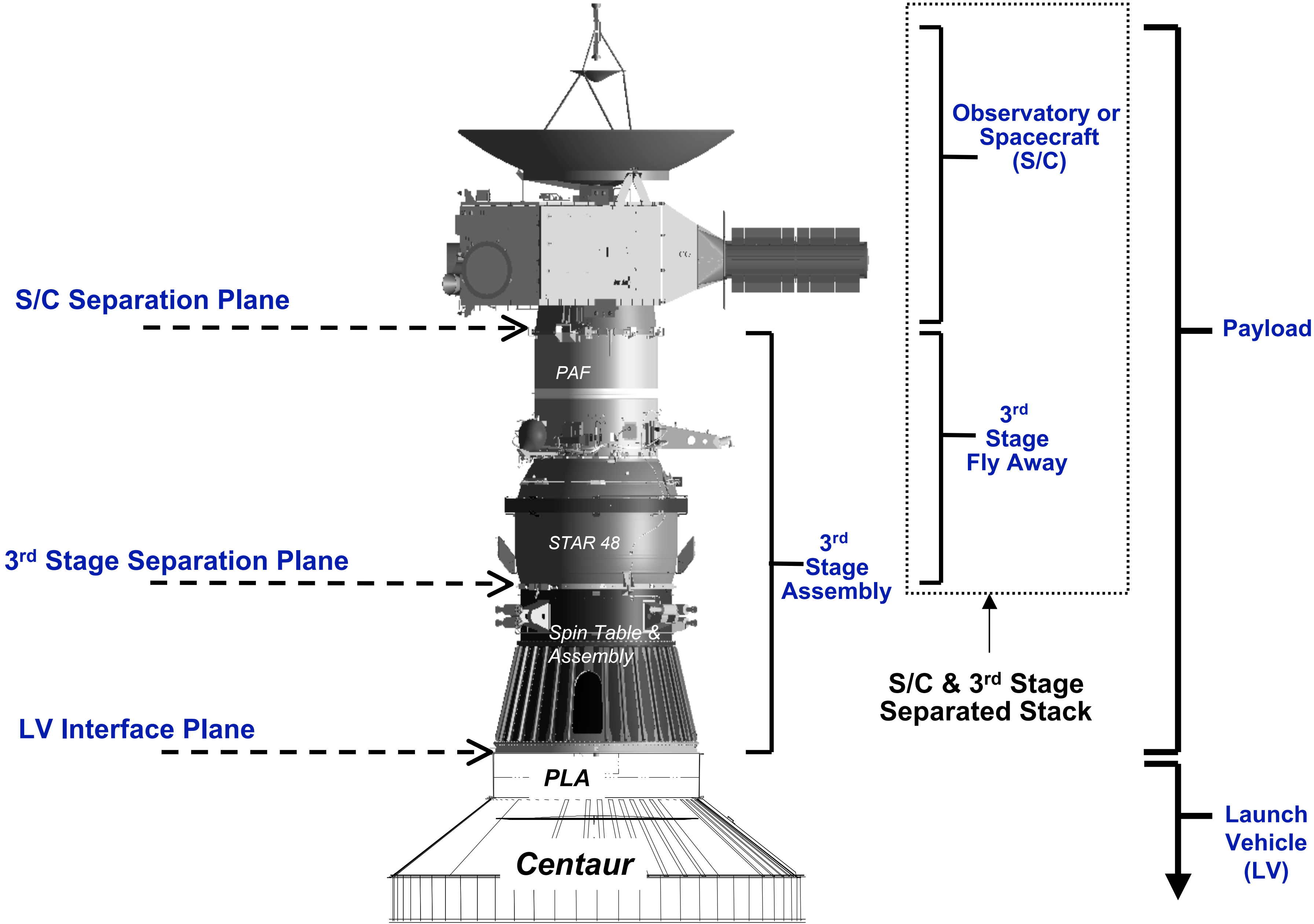
C3: 164 km^2/s^2

S/C mass: 465 kg

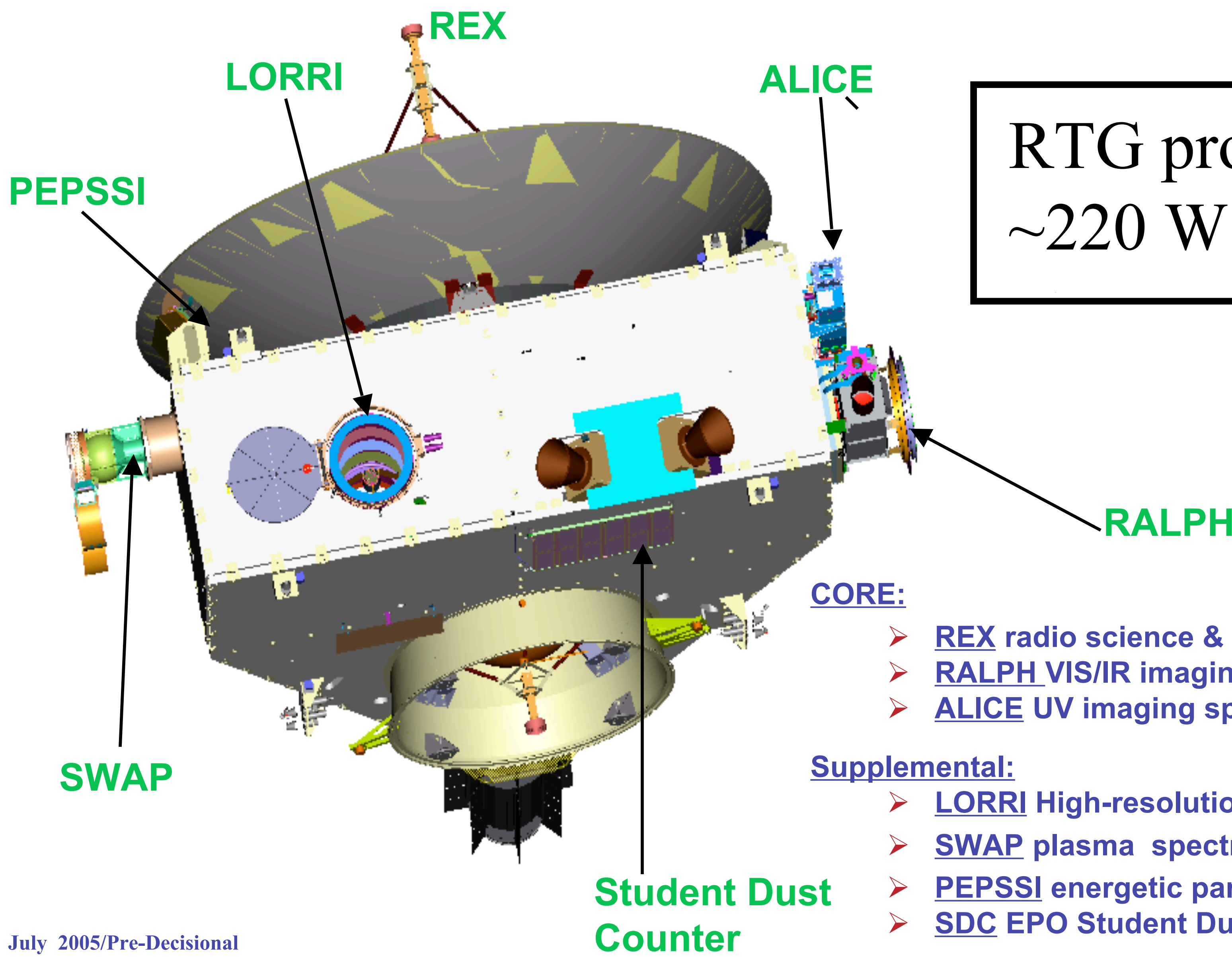
To Pluto Via Jupiter (encounter Feb. 28, 2007, at 32 R_{Jup})

Arrival at Pluto in July 2015 (C/A July 14, 11:59 UTC)

Payload Configuration



Instrument Payload



RTG provides ~220 W at Pluto

CORE:

- REX radio science & radiometry
- RALPH VIS/IR imaging & spectroscopy
- ALICE UV imaging spectroscopy

Supplemental:

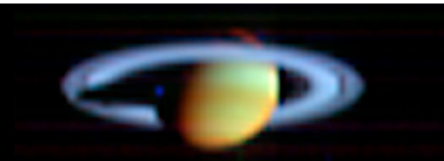
- LORRI High-resolution imager
- SWAP plasma spectrometer
- PEPSSI energetic particle spectrometer
- SDC EPO Student Dust Counter

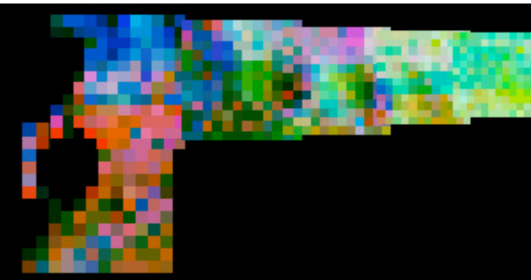
Summary Measurement Objectives (PKB Science Definition Team)

Group 1 Objectives:
Characterize the global geology and morphology of Pluto and Charon
Map surface composition of Pluto and Charon
Characterize the neutral atmosphere of Pluto and its escape rate
Group 2 Objectives:
Characterize the time variability of Pluto's surface and atmosphere
Image Pluto and Charon in stereo
Map the terminators of Pluto and Charon with high resolution
Map the composition of selected areas of Pluto & Charon at high resolution
Characterize Pluto's ionosphere and solar wind interaction
Search for neutral species including H, H_2, HCN, and C_xH_y, and other hydrocarbons and nitriles in Pluto's upper atmosphere
Search for an atmosphere around Charon
Determine bolometric Bond albedos for Pluto and Charon
Map the surface temperatures of Pluto and Charon
Group 3 Objectives:
Characterize the energetic particle environment of Pluto and Charon
Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Charon
Search for magnetic fields of Pluto and Charon
Search for additional satellites and rings

Imaging Spectroscopy

- Galileo NIMS
- Cassini VIMS (Visible-Infrared Mapping Spectrometer)
- OMEGA on ESA's Mars Express
- Mars Reconnaissance Orbiter CRISM
- AVARIS (Earth applications)
- Others



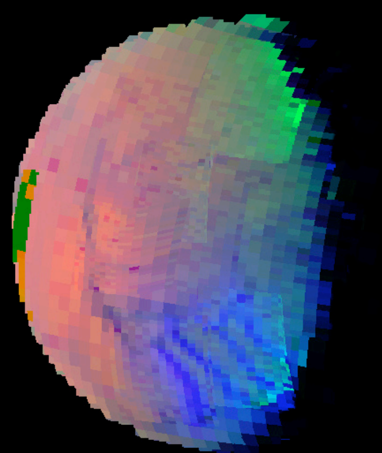


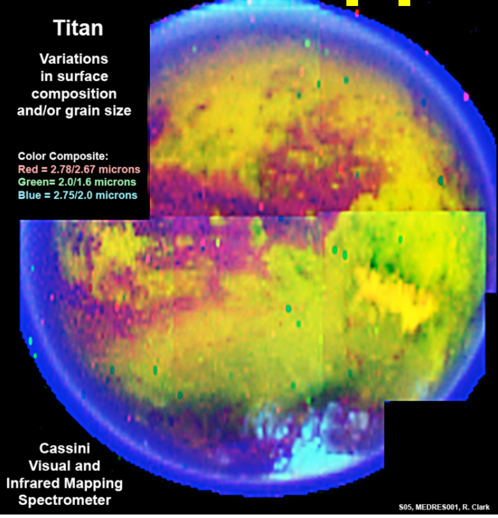
RGB Mineral Map:
Red =CO2 at 4.26 microns
Green = 1-micron albedo
Blue = 2-micron Ice

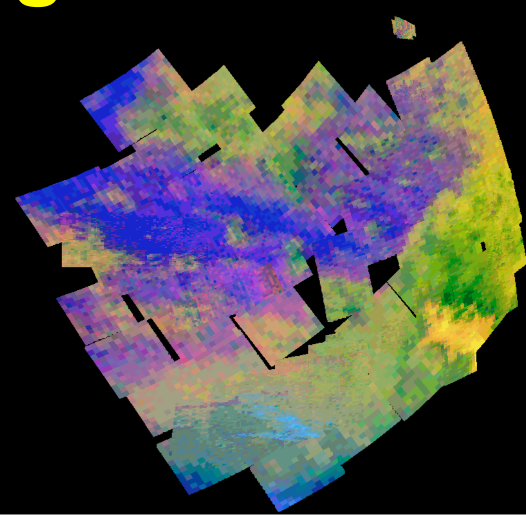
Cassini VIMS

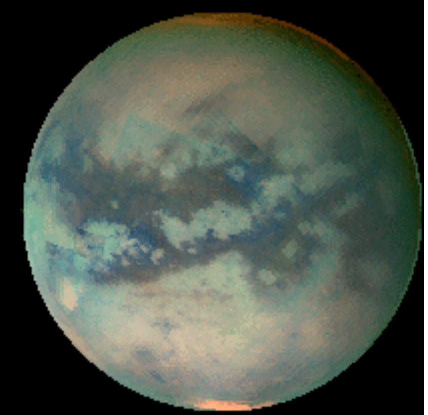
Visual and Infrared Mapping Spectrometer

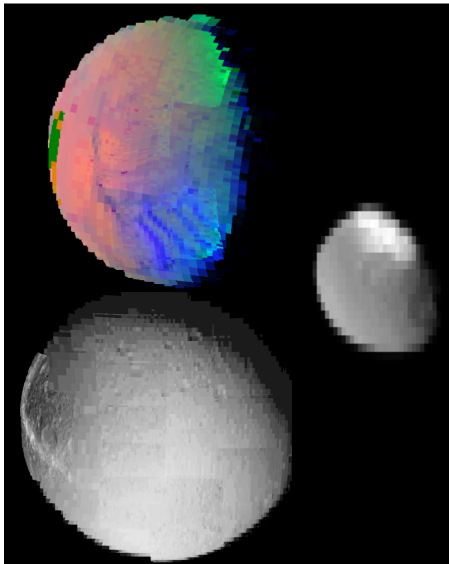
- An *Imaging Instrument* that enables compositional mapping

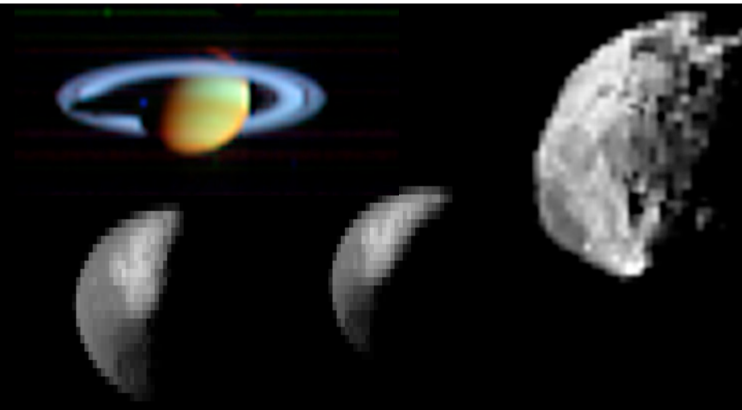


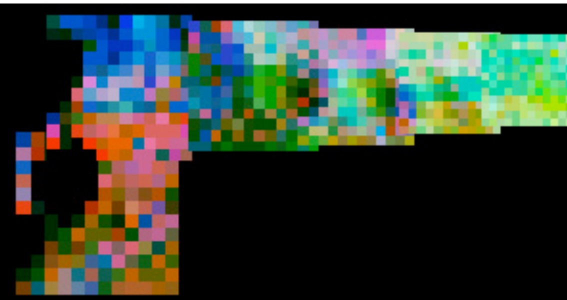










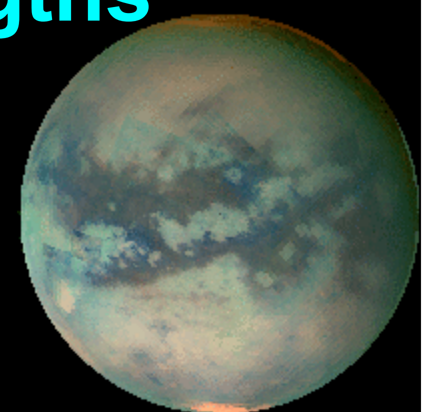


RGB Mineral Map:
Red =CO2 at 4.26 microns
Green = 1-micron albedo
Blue = 2-micron Ice

VIMS

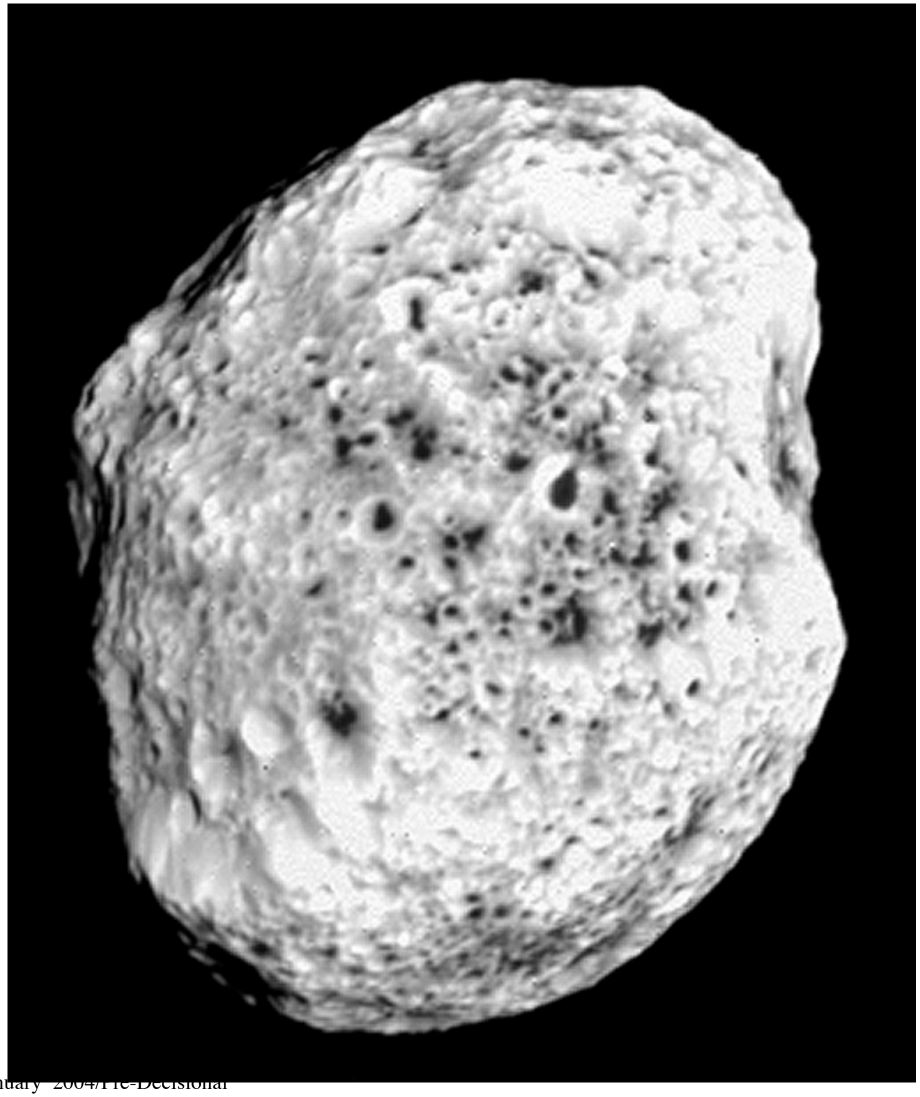
Visual and Infrared Mapping Spectrometer

- 0.35 to 5.2 microns in 352 wavelengths
- IFOV: 0.5 x 0.5 mrad (standard)
- High resolution IR: 0.5 x 0.25 mrad
- High resolution VIS: 0.17 x 0.17 mrad
- Images up to 64 x 64 pixels square.



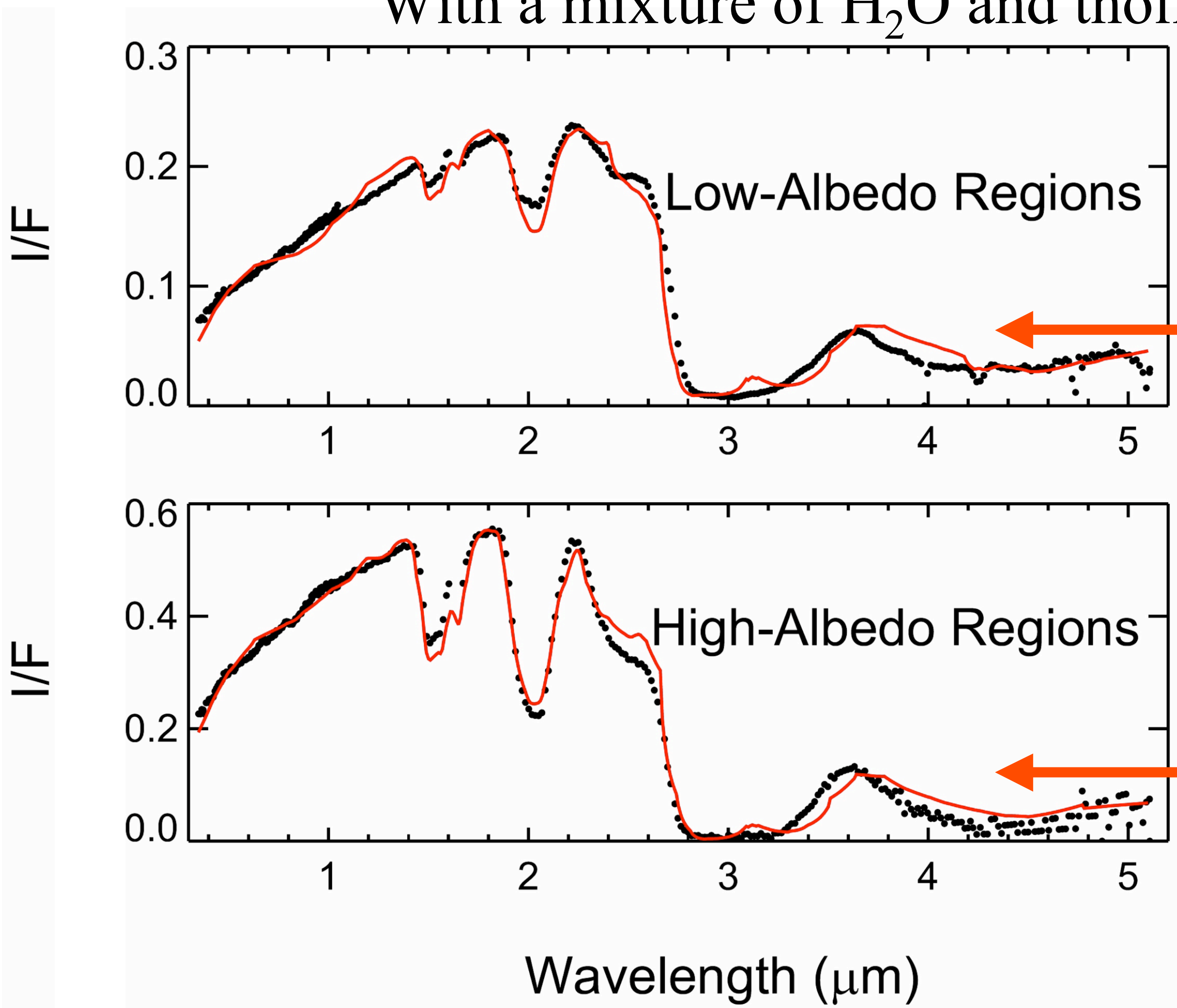
Hyperion: Irregular shape, Chaotic rotation, Longest dimension 300 km

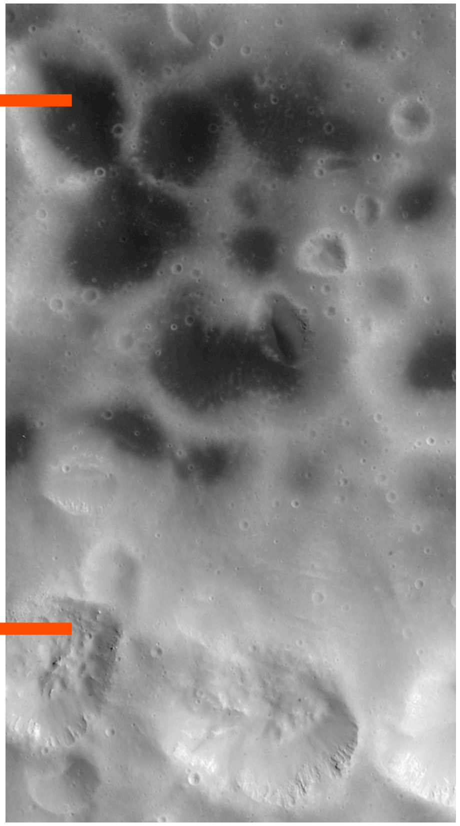
Mean density ~0.6 g/cm^3 , Highly porous

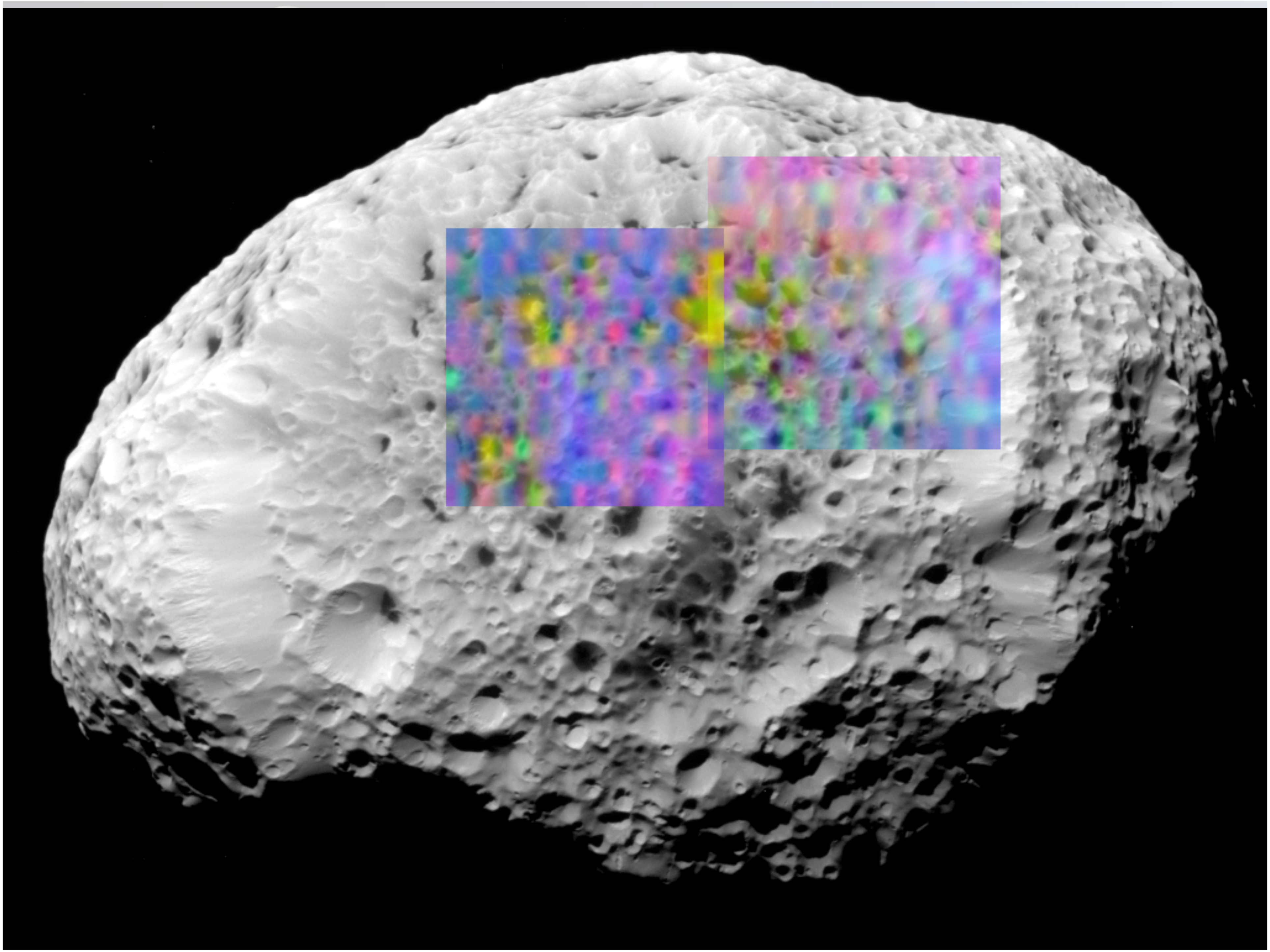


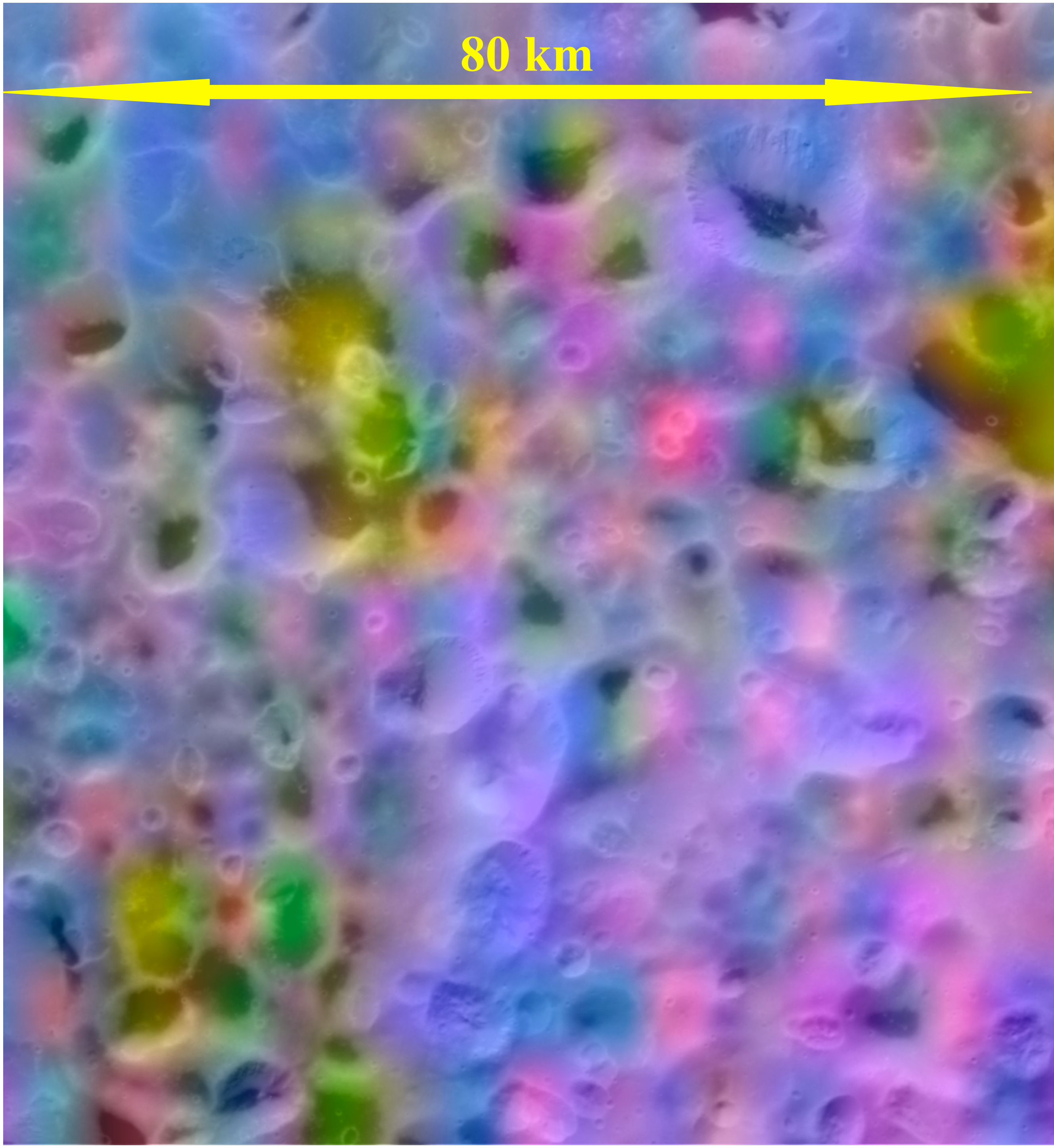
Hyperion's two main surface units can be modeled

With a mixture of H_2O and tholin









Compositional Map of Hyperion

Cassini VIMS

<u>Color code:</u>

<u>Blue</u> = H_2O band depth

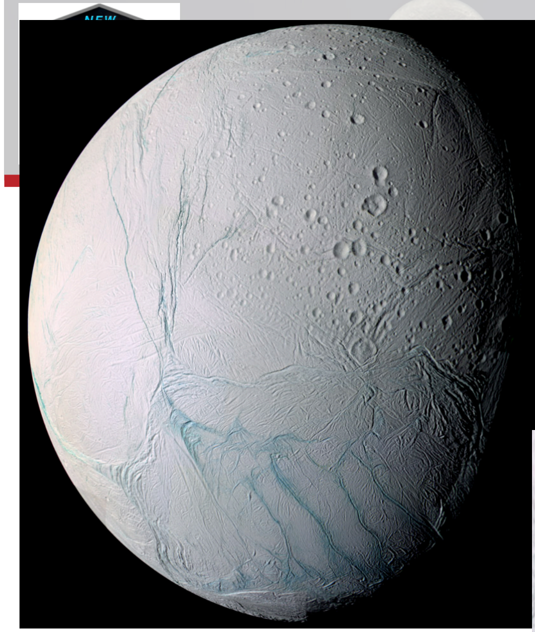
<u>Red</u> = CO_2 band depth

<u>Green</u> = 2.42 µm band

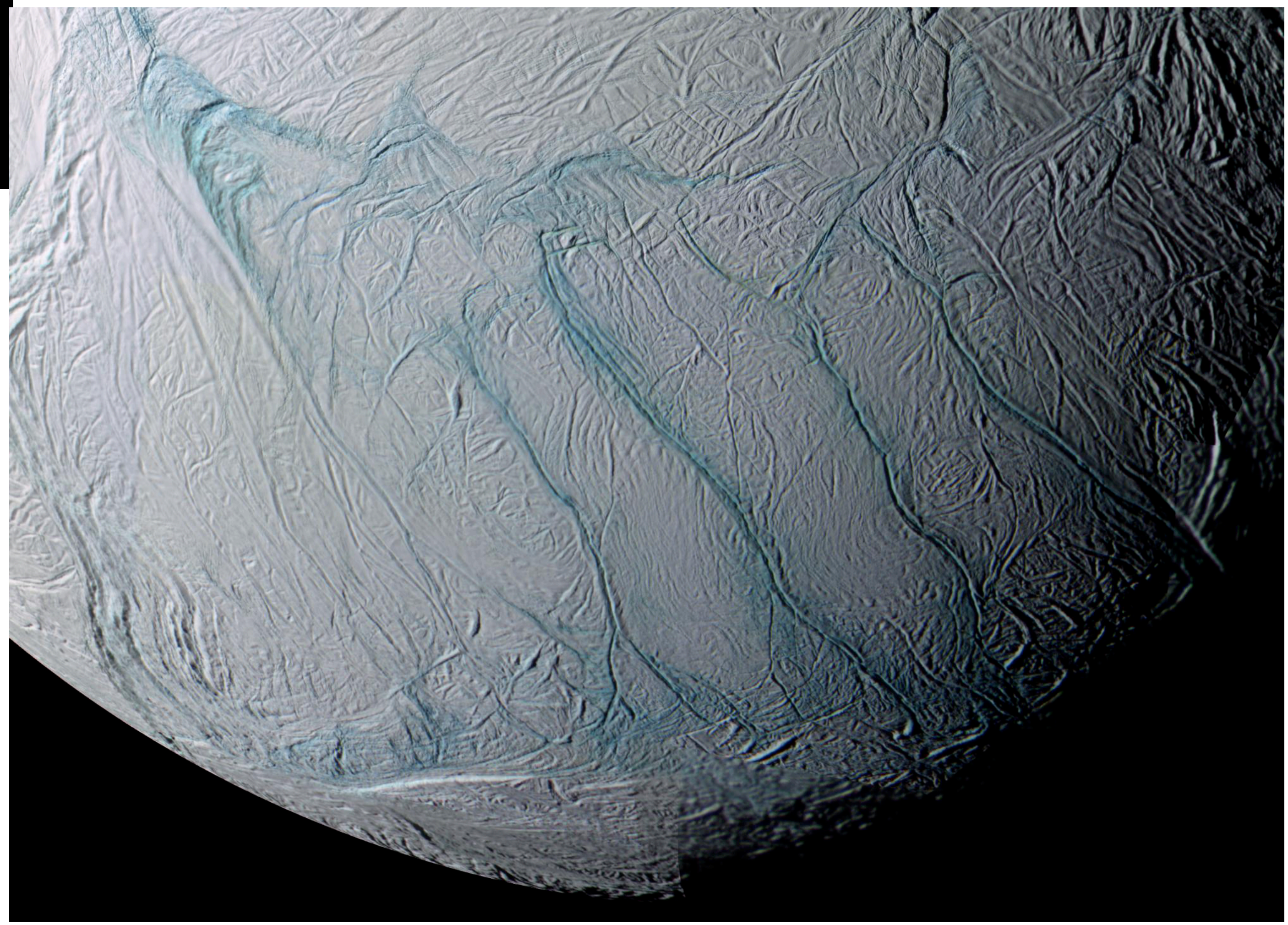
Yellow = CO_2 + 2.42 µm

Magenta = H_2O + CO_2

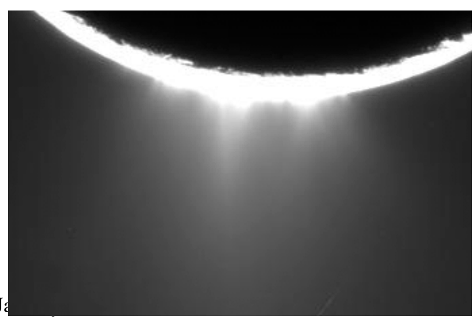
Enceladus

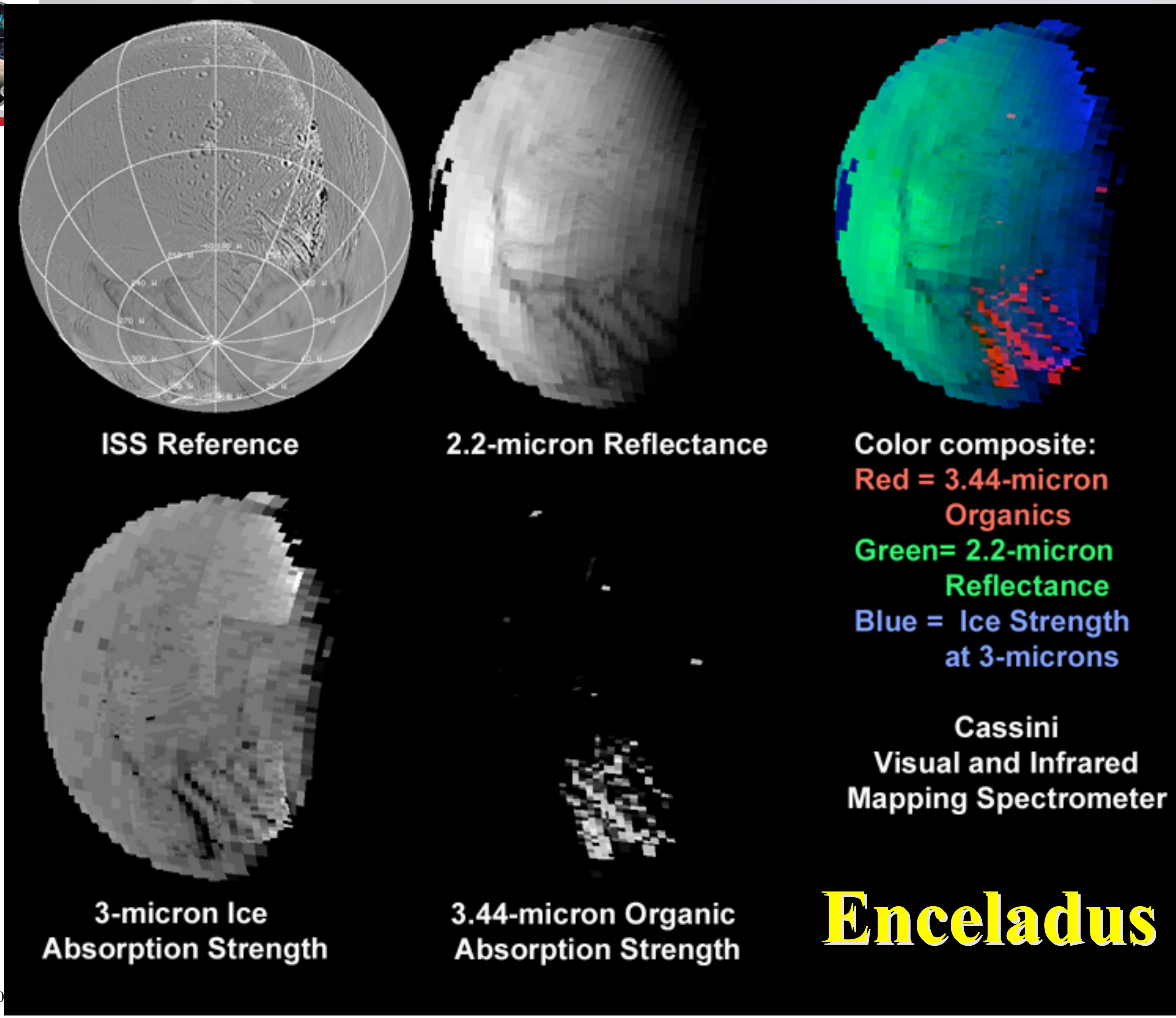


The “Tiger Stripes”



The plumes originate at the South Pole



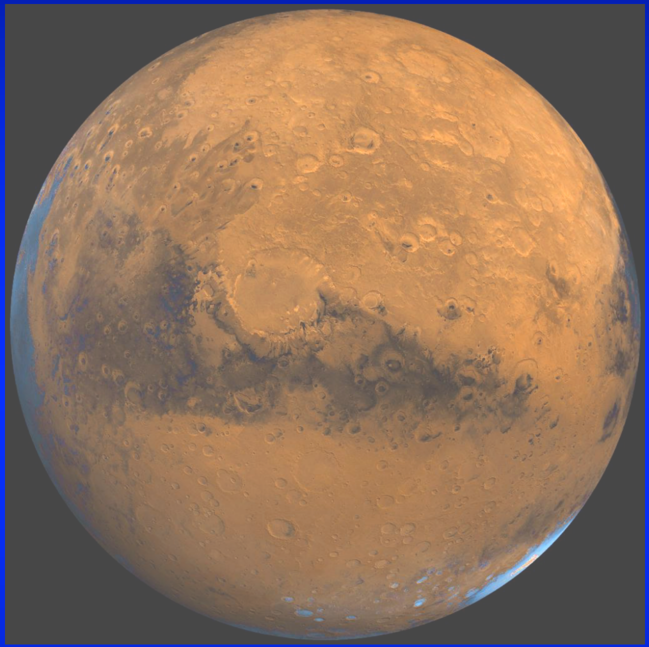

ISS Reference
2.2-micron Reflectance
Color composite:
Red = 3.44-micron Organics
Green= 2.2-micron Reflectance
Blue = Ice Strength at 3-microns
3-micron Ice Absorption Strength
3.44-micron Organic Absorption Strength
Cassini Visual and Infrared Mapping Spectrometer
Enceladus

H_2

CRISM maps Mars at 18 m/pixel

Orbits Mars on

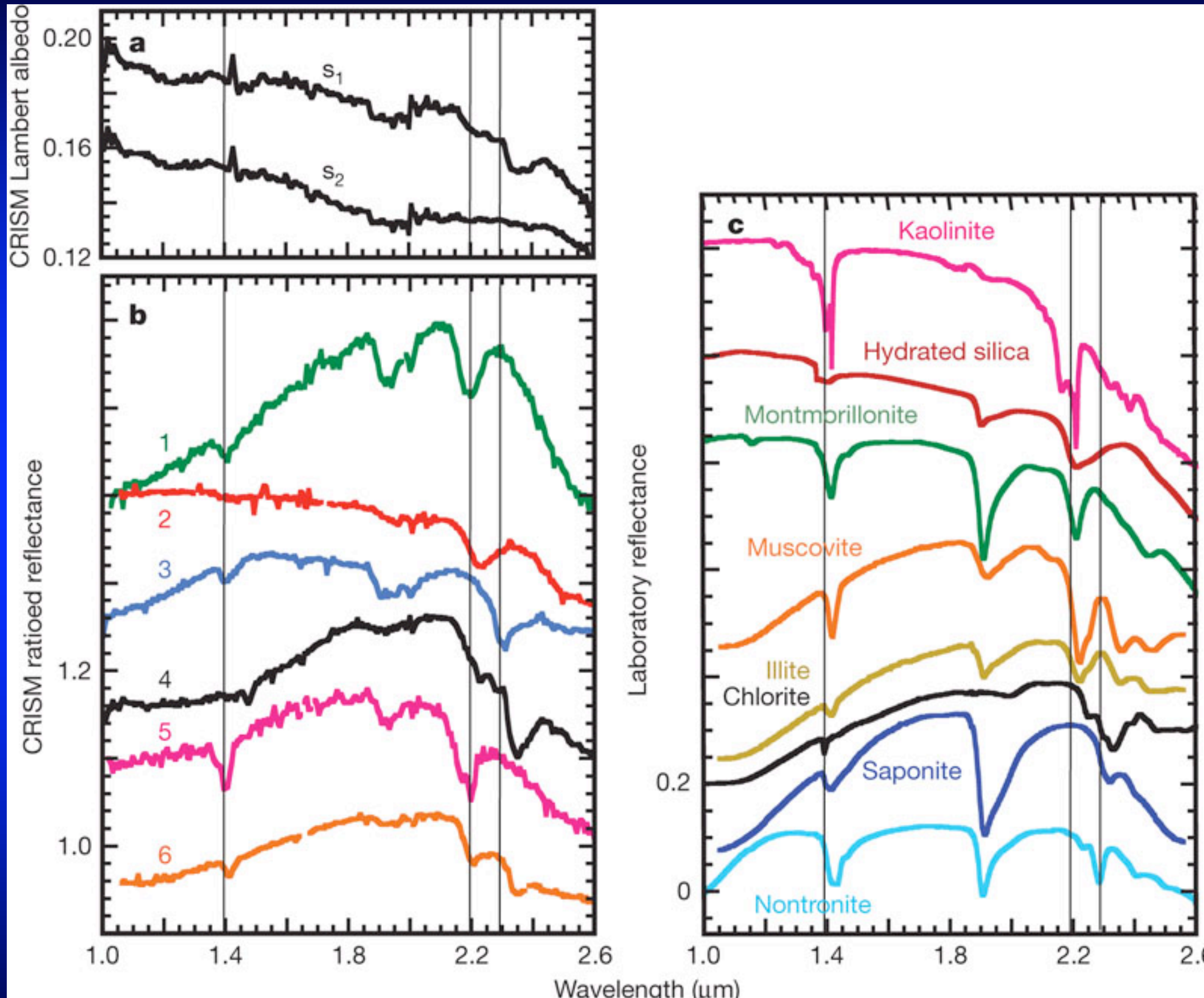
Mars Reconnaissance Orbiter



- Mass   33 kg
- Power usage   47 W
- 100 mm aperture telescope
- Wavelength range 0.36 – 4 µm
- Images Mars simultaneously at 72 wavelengths (selected from suite of 544 available wavelengths)

CRISM Spectra of Mars

Spectral signatures of hydrous minerals found on Mars

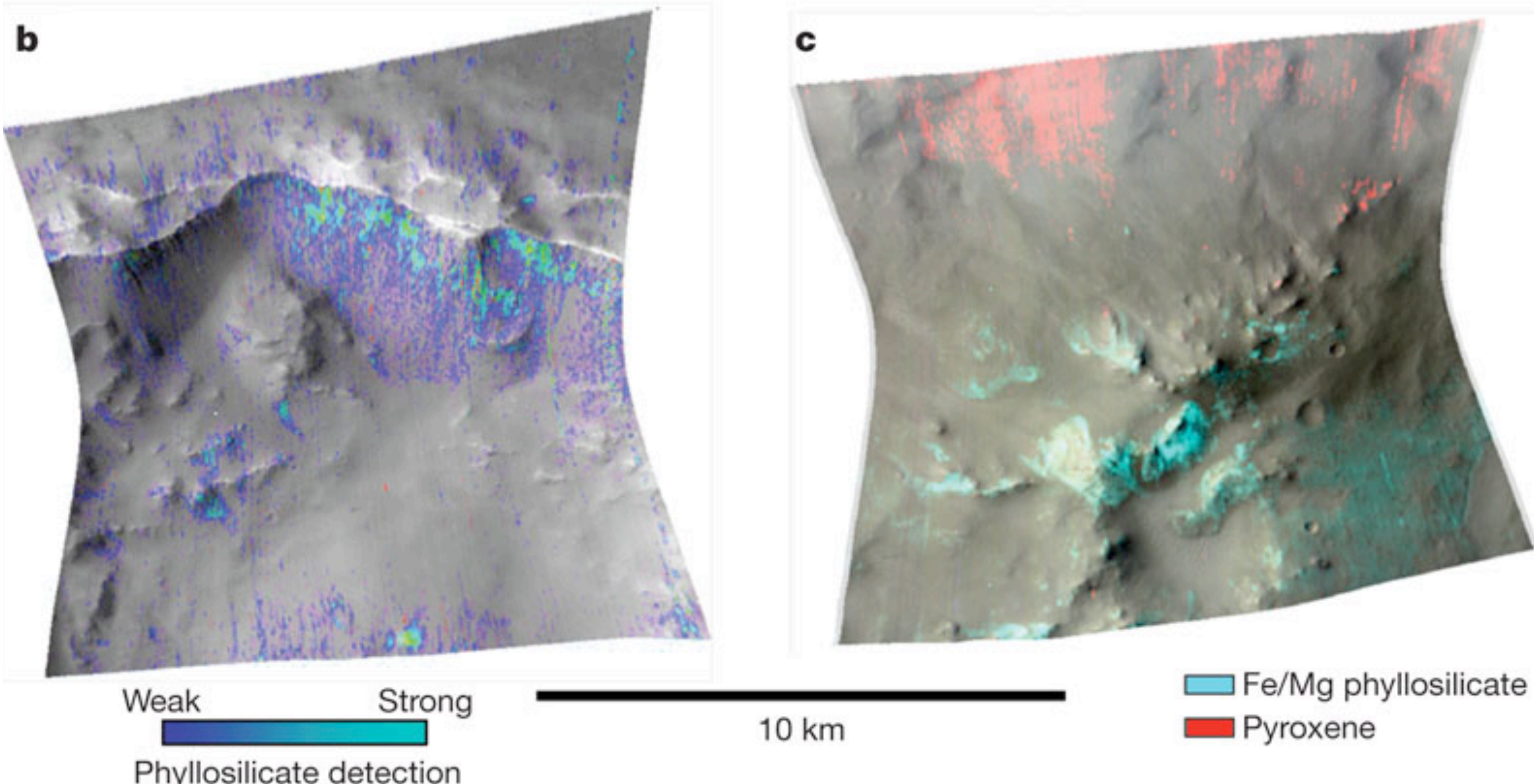


Mars Data

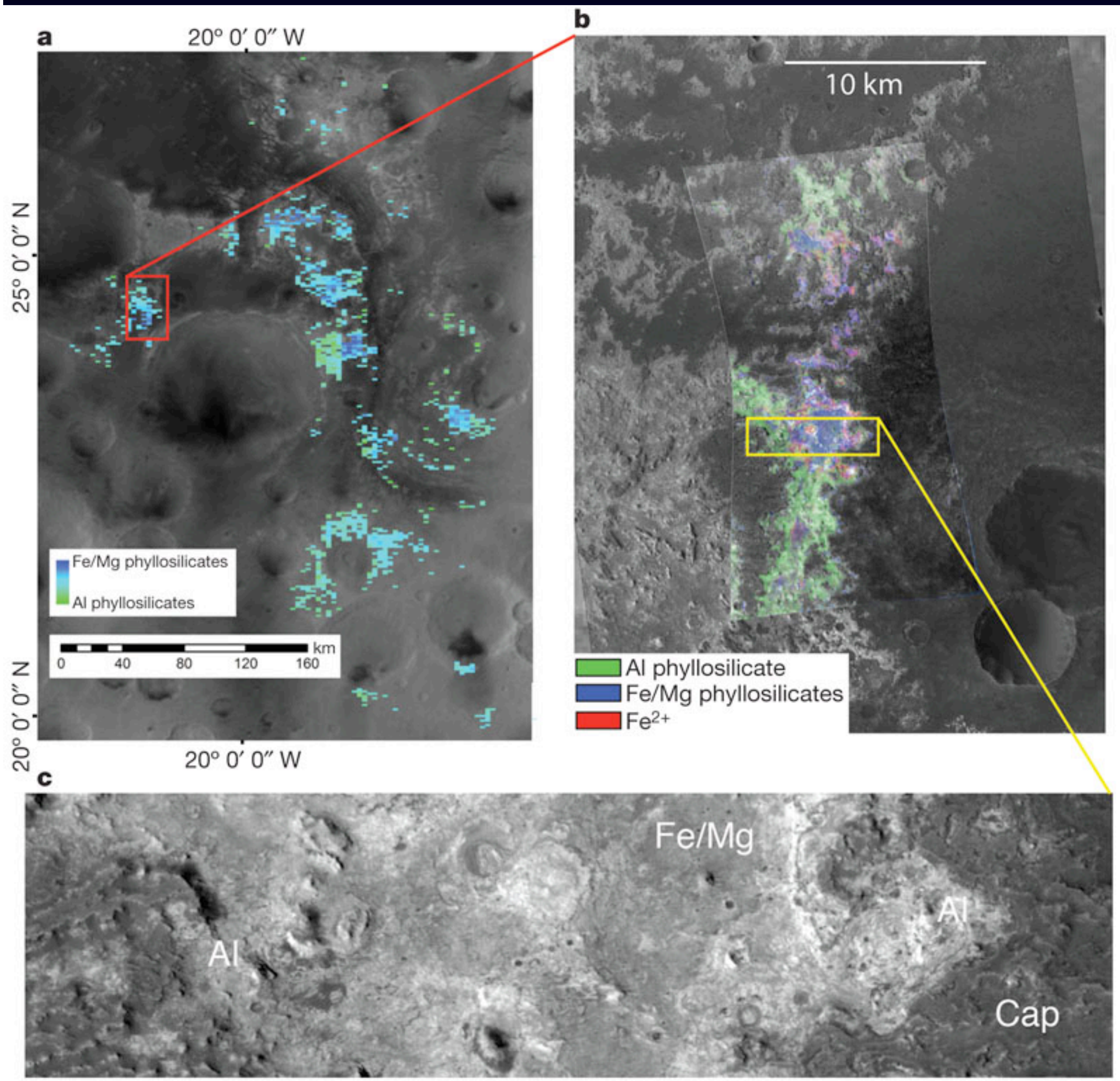
Lab Spectra

Compact Reconnaissance Imaging Spectrometer for Mars
= CRISM

On *Mars Reconnaissance Orbiter*



Maps of hydrous silicates, indicating mineral interactions with liquid water,
at a spatial scale of 18 meters/pixel


a
20° 0′ 0″ W
25° 0′ 0″ N
20° 0′ 0″ N
Fe/Mg phyllosilicates
Al phyllosilicates
km
0
40
80
120
160
b
10 km
Al phyllosilicate
Fe/Mg phyllosilicates
Fe2+
c
Fe/Mg
Al
Al
Cap

Physical properties of KBOs: <u>What we want to know</u>

- ORIGINS
- Composition (surface and atmosphere)
  - Ices, minerals, organic molecules
- Geological processes on surface and interior – past and present
- Relationship to comets
- Relationship to volatiles and organic materials on terrestrial planets

Physical properties of KBOs: What do we measure ?

- Surface composition with high spatial resolution
- Mass spectra of neutrals and ions in tenuous atmosphere
- Isotopic composition (C, H, O, N)
- High-resolution images, maximum surface coverage
- Mass, dimensions, figure, rotation, satellites
- Magnetic field

What is needed to explore Kuiper Belt Objects ?

Key Measurements

- High-resolution surface imagery
- Atomic, molecular, and isotopic composition of the surface materials
  - Ices, minerals, organic materials
  - These measurements connect KBOs to material in the nascent molecular cloud from which Solar System formed, and tell about their chemical evolution since their origin(s)
  - They connect KBOs with comets, planets, and small bodies in the Solar System
- Composition of atmospheric gases and sputtered surface materials
  - As above

Next Generation Spacecraft Requirements

- Capacity for much larger instruments
  - Larger apertures
  - More capable detectors (λ range, sensitivity)
- Mass spectrometers
  - Large mass range, high sensitivity
- Power (> few kW)
- High data volume and rate
- Surface Probes
- Autonomy and other operational innovations (distances measured in light-hours)

Primary *New Horizons* KBO Science

- Geologic, Photometric, and Color Mapping
- Surface Composition Mapping (H_2O, CO, CO_2, CH_4,…)
- Thermal Variegation Mapping (to 2 K at ~10 km scales)
- Search for Atmospheres to <1 Nanobar (10^{-4} Pluto)
- Search for Surface Sputtering Products
- Stereo Surface Mapping
- Mass, Density, Figure Measurements
- Crater Counts for Impactor Diameters Down to <20 m
- Satellite Searches to <1 km, and Follow-up Studies